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CONSERVATION TILLAGE FOR SOYBEAN IN THE U.S. SOUTHEASTERN COASTAL PLAIN*

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ABSTRACT

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Double cropping of soybean has progressed less rapidly in the U.S. Southeastern Coastal Plains than expected by the ample rainfall and long frost-free season. Post-emergence herbicides, the management of plant residues to reduce water use by cover crops, and a no-till planter with a combination subsoiler are the innovations that have facilitated this new production. Full-season soybean (*Glycine max* L.) was planted following a grazed cover crop of winter rye (*Secale cereale* L.) or late-season soybean was planted following winter wheat harvest. In both cases, a special planter was used with an integral subsoil shank ahead of the opener. Full-season soybean under conservation tillage produced yields equal to or better than yields in conventional clean tillage. In a dry summer, soybean yields under conservation tillage exceeded conventional tillage because of suppressed early biomass production which conserved stored soil water and favored growth during the reproduction phase of the crop-cycle. Late-season soybean yields behind wheat favored the conservation tillage practice of in-row subsoil-planting into stubble. However, planting in burned-off wheat stubble produced the highest yields in this study. In a dry spring, the cover crop accelerated soil water use which resulted in lower soybean yields under conservation tillage. Comparisons of 76 vs. 97 cm row spacing were inconclusive, but the trend suggests that wider rows conserve water under periods of drought and that the narrower-row configuration favors adequate water regimes.

INTRODUCTION

Conservation tillage in the U.S. Southeastern Coastal Plain (US-SCP) is needed (Larson, 1981) and has been encouraged by the early successes of Phillips and Young (1973) with no-till in the southeastern U.S., and the more recent production demands for multicropping systems in a climate

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that has a combined average annual rainfall of 110 cm and more than 280 frost-free days (Kronberg et al., 1965). This potential can be realized because of new technology, such as: (1) planting equipment that uses an integral in-row subsoiler (Harden et al., 1978); (2) new species-specific post-emergence herbicides; (3) new techniques, such as rope wicks, recirculating sprayers, directed and shielded sprayers, controlled droplet applicators, and atomizing sprayers, for post-emergence application of both non-selective contact and systemic herbicides. These developments (Palmer, 1981) have all facilitated conservation tillage for field crops in the U.S. Southeastern Coastal Plain (US-SCP). However, conservation tillage successes for maize (*Zea mays* L.), on major land resource areas (Austin, 1965) 121—123 in Kentucky, have not been repeatable on the flatter sandy soils of the hotter and more humid coastal plain (MLRA No. 133). On sloping fields, surface residues reduce losses of water, nutrients, pesticides and the soil itself. Consequently, conservation tillage produces higher maize yields than conventional tillage (Phillips et al., 1981). However, in the US-SCP, the nearly flat topography, low water and nutrient retention of the soils, and higher disease and insect pressures of a humid climate reduce the competitive advantage of conservation tillage (Campbell et al., 1984).

Blevins and Thomas (1981) noted that for maize grown on fragipan soils such as the Grenada series, conservation tillage yields were not comparable to conventional tillage yields because typically these soils have restrictive horizons at approximately the 60-cm depth. Similarly, Paleudults, Hapludults and Paleaquults of the US-SCP obstruct root penetration at the 20- to 40-cm depth (Campbell et al., 1974; Doty et al., 1975; Reicosky et al., 1977; Trouse and Reaves, 1980) because of tillage pans or the presence of a dense, genetic E horizon. These physical properties particularly restrict the more fibrous root system of maize.

However, determinate soybean (*Glycine max* L.) is less susceptible than maize to yield-loss from short-term drought because it grows and forms seed over a prolonged period of time. Provided complete canopy cover is achieved by flowering, tillage systems have little effect on yield. Soybean can be double-cropped with small grain in the US-SCP. Consequently, conservation tillage in this region has become more oriented toward soybean than maize. In 1983 conservation tillage was used on 42 300 ha of soybean and 14 000 ha of maize in South Carolina (USDA-SCS, 1983). A similar tillage distribution pattern for the 2 crops exists in Georgia (Reichert, 1979). However, in both instances the greatest proportion of conservation tillage was not from the coastal plain but rather from the sloping Piedmont physiographic region (MLRA No. 136).

Early deep tillage work in South Carolina and Georgia (Peele et al., 1974; Parker et al., 1975) demonstrated that conservation tilled soybean produced yields comparable to conventional tillage systems provided in-row subsoiling was employed. Later tillage studies conducted in the upper Coastal Plain produced similar results. Touchton and Johnson (1982) showed that in-row subsoiling benefited both the soybean crop and the following grain crop on

Appling (Fragiaquic Paleudult) and Cedarbluff (Typic Hapludult) soils which have traffic pans or fragipans. Penetrometer measurements by Campbell et al. (1974) and Cassel et al. (1978) showed that subsoiling is also necessary to allow root penetration through the dense E horizon of the Varina (Plinthic Paleudult) and Norfolk (Typic Paleudult) series of the coastal plain. Once roots penetrate those dense horizons, they proliferate in the B horizon. Rooting in the B horizon usually accounts for about 50% of the total rooting volume because of a lower bulk density, a lower soil strength at a given matric potential, and the presence of the more mobile nutrients.

The objectives of this research were to develop an understanding of the benefits and limitations of conservation tillage for southern determinate soybean. Residue management was evaluated for each of the 2 following double cropping arrangements for soybean: (a) soybean planted into winter rye (*Secale cereale* L.) that has been grazed; (b) soybean planted after wheat (*Triticum aestivum* L.) harvest. Soybean double cropped after winter rye is planted much earlier than when planted after wheat harvest. In the former case, a "full-season" soybean is planted, and in the latter case, a "late-season" soybean is planted.

MATERIALS AND METHODS

These different groups of studies were conducted over a 4-year period (1978—1981) on Norfolk loamy sand (Typic Paleudults) in the coastal plain of South Carolina. Before the fields were used experimentally, they had been row cropped in soybean, cotton (*Gossypium hirsutum* L.), maize, and tobacco (*Nicotiana tabacum* L.) for many years. Occasionally, winter rye (*Secale cereale* L.) cover crops were grown for spring grazing. In the first group of studies (1978—1980), full-season soybean was planted in mid-May following a rye cover crop that was usually grazed by cattle before planting. In the second group of studies (1979—1981) soybean was planted into harvested grain stubble in the last week of June. In the third group of studies (1980—1981), soybean was double crop planted after various residue management treatments (Table I).

TABLE I

Tillage management methods used to condition plant residues before planting

Symbol	Tillage system	Days before planting	Field operation on cover crop
DP[a]	Conventional	Periodically, 1	Disk
DE	Conventional	20, 1	Disk
DL	Conventional	1	Disk
HE	Conservation	20	Non-selective herbicide
HL	Conservation	1	Non-selective herbicide

[a]DP treatments received disking as necessary after harvest to maintain a weed-free condition.

Herbicides applied to HE and HL were as follows: Paraquat (1.1′-dimethyl-4.4′-bipyridinium) at 5 kg ha^{-1} a.i.; Alachlor [2-chloro-2′,6′-diethyl-N-(methoxymethyl)acetanilide] at 2 kg ha^{-1} a.i. with water at the rate of 374 l ha^{-1}. When evening primrose (*Primula* spp.) or marestail (*Conyza canadensis*) weeds were present, glyphosate (N-phosphonomethylglycine) was substituted for paraquat at a rate of 0.9 kg ha^{-1} a.i.

In plots where residue was incorporated (DP, DE, DL) metribuzin (4-Amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4H)-one) at 0.3 kg ha^{-1} a.i.; trifluralin (α,α,α-Trifluoro-2,6-dinitro-*N,N*-dipropyl-p-toluidine) at 0.6 kg ha^{-1} a.i.; vernolate (S-propylid propylthiocarbamate) at 1.1 kg ha^{-1} were incorporated about 1 week before planting. Early weeds except cocklebur (*Xanthium pennsylvanicum*) were effectively controlled. To control cocklebur, bentazon (3-(1-Methylethyl)-1*H*-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide) was applied over the canopy at 1.1 kg ha^{-1}. Nutgrass (*Cyperus esculentus*) was controlled with a directed paraquat spray at 0.3 kg ha^{-1} a.i.

Unless specified otherwise, the treatments were at least 1 ha^{-1} in area and were laid out in a randomized complete block design. The row spacing was 97 cm. The large plot size was needed to more adequately test the tillage treatments. Treatments in the third group of studies were laid out in a split-split plot randomized block design with 3 replications in 1980 and 4 replications in 1981. Each tillage plot was equally divided and planted to soybean on 76- and 97-cm row spacings. Each row spacing plot was again

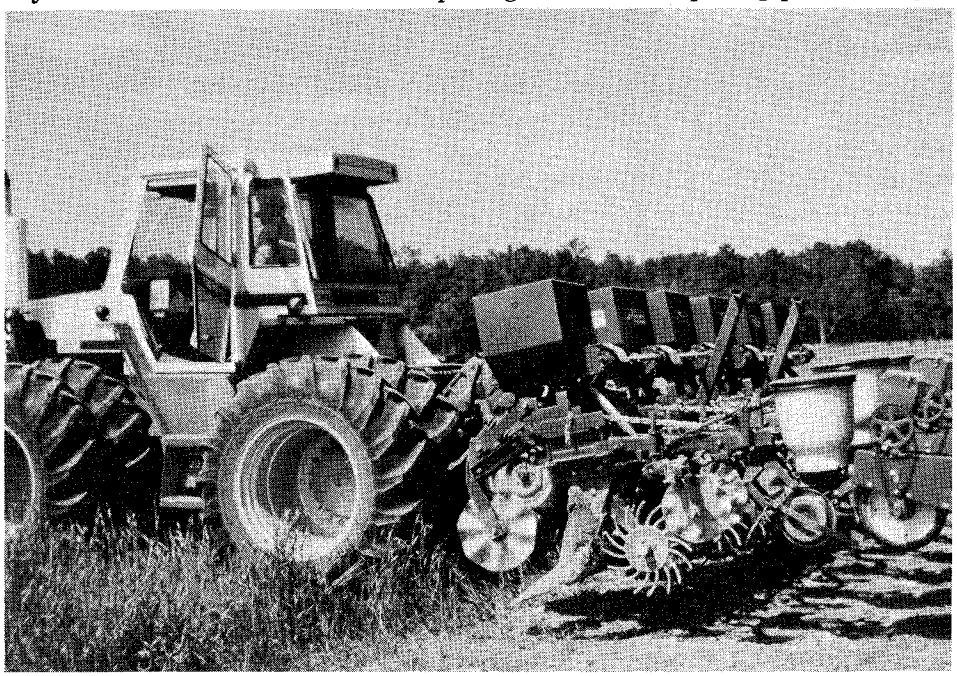

Fig. 1. Six-row conservation tillage planter equipped with dry fertilizer distributors, insecticide hoppers, and a rear-mounted herbicide spray system (not visible).

split and the 3 soybean cultivars, Ransom and Bragg (maturity group VII) and Coker 338 (maturity group VIII) were planted.

All soybean plantings were made with an integral no-till planter-subsoiler (Harden et al., 1978). A 50-cm diameter fluted coulter for cutting residues was followed by a subsoil shank operated at a 46-cm depth. The subsoil slot was smoothed by a spiked rolling cultivator and a 33-cm diameter fluted coulter mounted on each side and slightly to the rear of the subsoil furrow. Seed was planted by a trailing John Deere Model 71 flexi-planter with double-disk openers (Fig. 1).

Each autumn 1120 Mg ha^{-1} of lime was applied in an effort to maintain a soil pH near 6.0. Soil test levels of P and K were maintained by applying 25 and 50 kg ha^{-1}, respectively, of P and K each autumn. Each spring 60 kg ha^{-1} of N was broadcast to improve the grazing capacity of the cover crop in the field-scale studies.

RESULTS AND DISCUSSION

Soybean double cropped after winter rye

In earlier experiments, only 2 treatments (DE and HL in Table I) were compared. In the 1979 comparison with a total of 24 sub-samples from 3 field sites, mean soybean yields were 2.20 and 2.30 Mg ha^{-1}, for the DE and HL treatments respectively. These were not different statistically. In 1980, the comparison at 1 tested site gave mean soybean yields of 1.76 and 1.93 Mg ha^{-1}, respectively, for the DE and HL treatments. This difference was statistically different at the 5% level of probability.

In 1980, significant reduction in soybean yield was caused by 2 pronounced drought periods. The first occurred at planting, and the second occurred in late August to early September (Fig. 2). Early shoot growth was initially slower in the HL treatment than in the DE treatment. The slower development of shoots in HL treatment was the result of water use by the cover crop before planting the soybean crop. The weather was much drier in 1980 in the months of April, June, August, October, November and December than in 1979. In the HL treatment, the rye cover crop grew until soybean was planted on 13 May 1980, whereas the rye cover crop in the DE treatment was incorporated by disking on 17 April, 25 days before planting. The water content profile (Fig. 3) measured on May 15 (2 days after planting) shows the amount of water (2.46 cm) removed by the cover crop to the depth of rooting (37 cm) in the HL treatment in the 25 days following disking of the DE treatment. This extraction of available water from the HL treatment was both insufficient for optimal cover crop growth and furthermore rendered the soil too dry for soybean germination at planting on 13 May. Soybean planted in the HL treatment did not germinate until rain fell on 19 May. By this time, the soybean seedlings under DE had fully emerged. During the late drought (8 August—28 September) in 1980,

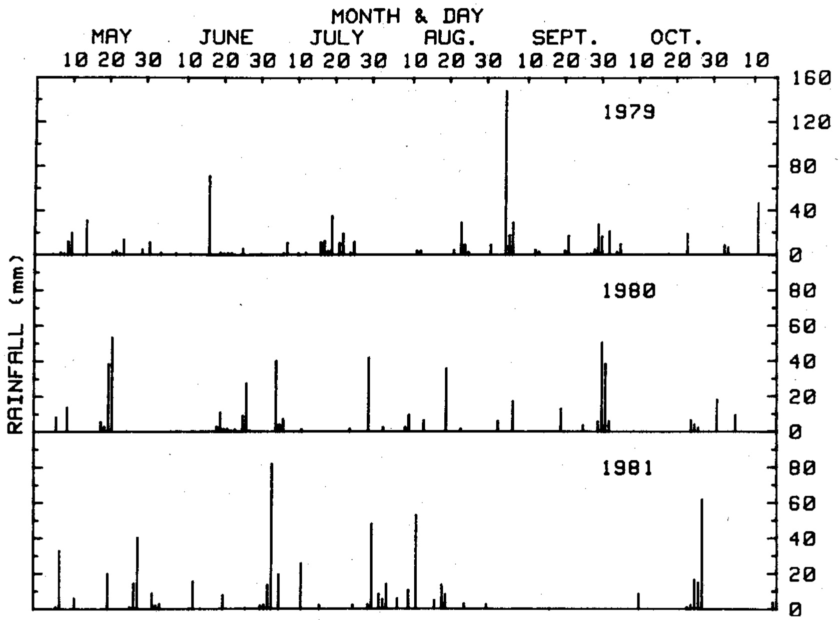

Fig. 2. Rainfall during the 1979, 1980 and 1981 growing season in Florence, SC.

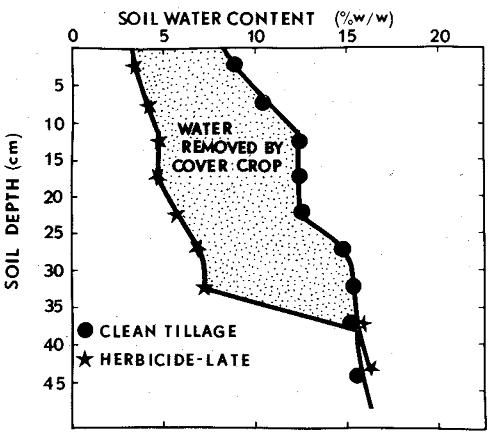

Fig. 3. Treatment effects on water extraction by a cover crop before seedling double cropping soybean.

there was only 6.13 cm of rain which was less than 50% of the water needed for the soybean crop.

In 1980, the plant population and stalk length were greater under DE on the 2 dates of sampling (Table II). Stem weight was greater in the DE treatment indicating that early growth exceeded that of HL. However, the weight of leaves, petioles, pods, and beans at the podfill growth stage were all greater in the HL treatment. Tensiometric data (not shown) indicated

TABLE II

Soybean biomass components as affected by treatment of cover crops into which soybean was double cropped in 1980 in Darlington County, SC

Plant component characteristic	Unit	Treatment (sampled 26 September)			Treatment (sampled 20 October)		
		DE	HL	LSD[a]	DE	HL	LSD[a]
Number plants	stalks/m	26.74	19.92	3.82	25.90	20.11	4.85
Stalk length	cm	30.70	27.55	2.18	27.21	23.00	3.24
Stalk weight	g/plant	8.71	8.30	NS	7.31	5.79	1.26
Leaves	g/plant	3.38	5.14	1.58	—	—	—
Petioles	g/plant	2.59	3.86	0.85	2.56	3.92	2.48
Pods and beans	g/plant	6.92	10.07	3.01	10.75	15.41	4.60

[a] $P = 0.05$.

early higher rates of water use from the profile in the DE treatment. Thus, water conserved in the HL treatment ultimately produced a higher yield in a very dry year.

Soybean double cropped after wheat harvest

Management of the wheat stubble before soybean seeding is important. The most common local preparation for soybean following small grain is to burn the stubble, disk the land, and then plant. In 1978 there were comparisons of planting after disking (DL), using a selective herbicide (HL), or burning the wheat residue. The treatments yielded 1.36, 1.85 and 1.99 Mg ha^{-1}, respectively, with a CV of 14.8 among treatments. In 1979, the DL treatment was compared with the HL treatment at 1 site and with the DL treatment which was preceded by burning the residue. In both cases yields were numerically, but not statistically lower in the DL treatment, 1.54 vs. 1.50 Mg ha^{-1} on the 1st site and 1.79 vs. 1.32 on the second site. Interestingly, if a 2-year mean is compared for the 4 treatments just described (DL, Burned + DL, HL, and Burn/planted) the respective yields are 1.39, 1.79, 1.70 and 1.99 Mg ha^{-1}. These observations concur with data from Mississippi (Sanford, 1982) which showed that late season soybean yields were highest and most consistent when no-till planted into burned stubble. This reflects water conservation and enhanced germination, weed control and more rapid nutrient cycling. Planting in standing stubble, however, conserves time, energy, and organic matter and produces higher yields than disking.

Rye residue and soybean management combinations on small plots

Observations in the 1978 and 1979 production scale studies prompted detailed evaluations of tillage, row-spacing, variety, and residue management. These studies were conducted identically in 1980 and 1981. Markedly different yields were obtained in these 2 years (Tables III and IV), because of different rainfall patterns and treatment-related water regimes.

TABLE III

Soybean yield (Mg ha^{-1}) for indicated row spacing and variety in 1980 in Florence, SC

Tillage system	76-cm row spacing				97-cm row spacing				Tillage system means
	Coker 338	Bragg	Ransom	All varieties	Coker 338	Bragg	Ransom	All varieties	
BA	1.01	1.19	1.25	1.15	0.92	0.91	1.09	0.94	1.05
DE	0.85	1.03	1.08	0.99	0.96	0.93	1.01	0.97	0.98
DL	1.01	1.10	1.08	1.06	0.81	1.06	1.14	1.00	1.03
HE	0.94	0.99	1.19	1.04	0.84	0.87	0.89	0.87	0.96
HL	1.08	0.81	0.92	0.94	0.99	0.97	1.02	0.99	0.96
Variety means	0.98	1.03	1.11		0.91	0.95	1.01		
Variety × spacing means					0.94	0.99	1.06		

TABLE IV

Soybean yield (Mg ha^{-1}) for indicated row spacing and variety in 1981 in Florence, SC

Tillage system	76-cm row spacing				97-cm row spacing				Tillage system means
	Coker 338	Bragg	Ransom	All varieties	Coker 338	Bragg	Ransom	All varieties	
DP	1.78	—	1.88	1.83	2.06	1.90	2.03	2.00	1.93
DE	2.06	1.90	2.00	1.99	1.86	1.90	2.05	1.94	1.96
DL	2.00	1.98	2.27	2.08	1.95	2.14	2.17	2.09	2.09
HE	1.60	—	1.68	1.64	1.89	1.93	2.09	1.97	1.84
HL	1.90	1.91	2.12	1.97	1.92	2.02	2.00	1.98	1.77
Variety means	1.87	1.93	1.99	1.93	1.94	1.98	2.07	2.00	1.96
Variety × spacing means					1.90	1.96	2.03		

In 1980 local rainfall was generally inadequate for high soybean production. Sufficient rainfall occurred to stimulate growth of the cover crop, which later accelerated extraction of stored water from the soil profile in February and April (3.9 and 3.1 cm, respectively). The soybean crop was planted 30 May 1980. June rainfall was only 4.0 cm. Later, during flowering and podfill, no significant rainfall was recorded from 18 August—17 September. However, a rain which totaled 13.4 cm fell in late September; this was too late to significantly improve soybean yields. Lower-than-normal rainfall occurred in October and November. Significant differences in yield did not occur among residue management regimes in 1980 (Table III). However, there was a trend for higher yields in treatments DP and DL, while lower yields occurred in treatments HL and HE.

Narrow row (76 cm) plantings yielded more than the wide row (97 cm) plantings in 1980. A significant interaction ($P \leqslant 0.05$) occurred between tillage systems and row-spacing treatments. Soybean in the DP 76-cm spacing treatment yielded significantly more than in the HE 97-cm row spacing. Also, in 1980 a significant difference ($P \leqslant 0.05$) occurred between Ransom (maturity group VII) and Coker 338 (maturity group VIII). The yield of Bragg (maturity group VII) was intermediate between the yield of Ransom and Coker 338. Ransom, grown in the tillage treatment that conserved water early in the crop cycle for the 76-cm row spacing, produced the highest yields of the 3 cultivars. This is in contrast to the lower-yielding, later-maturing Coker 338 variety in the 97-cm row spacing which was stressed by late drought. Evidently, rainfall in July and August favored Ransom more than the later-maturing Coker 338 in narrow rows under DP tillage.

Seasonal rainfall in both 1980 and 1981 favored earliness, with yield ranking in both years being Ransom highest, Bragg intermediate, and Coker 338 lowest.

In 1981, tillage, spacing and cultivar variables were significant at $P \leqslant 0.01$, 0.04 and 0.03, respectively. Average yields in 1981 were 2.00 Mg ha^{-1} and 1.93 Mg ha^{-1} for the 97- and the 76-cm row spacings, respectively. The respective yields in 1980 were 1.00 and 1.04 Mg ha^{-1}. In 1981 mean yields for HL and DL tillage treatments were 1.98 and 2.09 Mg ha^{-1}, respectively, as compared to 1.96, 1.93 and 1.84 Mg ha^{-1} for DE, DP and HE treatments, respectively.

The tillage by spacing interaction was also significant at $P \leqslant 0.01$ indicating that tillage effects differed between row spacings. Tillage treatments, DP and HE, produced the lowest yields in the narrow row spacing, whereas the 3 tillage treatments that had some residue remaining on the surface were unaffected by the row spacing. The treatments favoring water conservation, e.g., wide rows, maintenance of surface residues, early maturity groups, or late vegetative development, all resulted in increased yields and survived the late-drought best in 1981. In both years of the study, the August—September drought produced plant water-stresses that affected late-maturing soybean more than the early-maturing cultivars of Ransom and Bragg. Soybean crop production following small grains or cover crops is very dependent on the initial water regime and subsequent rainfall patterns.

CONCLUSION

Soybean planted into standing plant residues produced yields equal to or better than yields under conventional disk-plant tillage in the Southeastern coastal plain. This result is consistent with that reported by Westberry and Gallaher (1980) in Florida. Evapotranspiration by winter cover or small grain crops can affect water storage in the soil profile. Consequently, water extracted from the soil by weeds or vegetative cover crops can have a negative effect on the subsequent soybean crop if growing season rainfall patterns are not favorable. This factor is particularly critical in the sandy soils of the Southeastern coastal plain characterized by shallow effective rooting zones.

In 1980 higher soybean yields were observed under conservation tillage using rye as a winter cover crop. It was evident that smaller plants conserved soil water in the early vegetative period of growth which created a more favorable soil water regime in the reproductive growth period. In these studies, healthy, high biomass plants were produced in the clean tillage treatments, which resulted in smaller soybean yields than the slower-growing plants where residues remained on the soil surface in conservation tillage.

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